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THE ABSORPTION COEFFICIENTS OF SOFT X RAYS

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The X rays studied were produced at potentials ranging from 2500 to 10,000 volts. The tube (see fig. 1) in which they were generated was provided with a hot cathode, *C*, consisting of a flat spiral of tungsten wire, similar to the cathode in a Coolidge tube. The anode was of iron, but this has no bearing on the work reported here, as the characteristic radiation of iron did not appear in noticeable quantity. The rays escaped through an aluminum window, *W*, of 0.001823 grams per square centimeter, or of 0.000675 centimeters thickness, supported on wire gauze of 180 meshes to the inch. The rays, after passing through the sheets of absorbing material, entered the chamber of the gold leaf electroscope, by means of which their ionizing effect was measured.

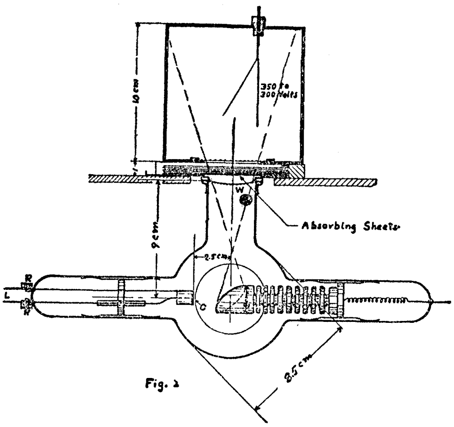

Fig. 1

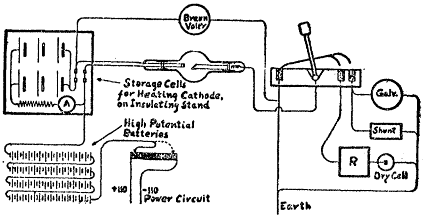

Fig. 2

The electrical connections are shown in figure 2. The cathode current from the tube was balanced by the current from the dry cell, when the resistance R was properly adjusted, by throwing the three point key to the right, and the galvanometer indicated when a balance was obtained.

The absorbing material consisted of sheets of gelatin, celluloid, aluminum foil and ordinary sheet aluminum. As the ratios between the absorption coefficients in these substances were found to be independent of the nature of the X rays, the observed absorption coefficients in gelatin and in celluloid have been reduced to equivalent absorption coefficients in aluminum, and the thickness of absorbing material through which the X rays past before the absorption coefficient was observed, has been similarly reduced to the equivalent thickness of aluminum. The ratios used for this reduction are

$$\frac{(\mu/\rho)\text{ celluloid}}{(\mu/\rho)\text{ aluminum}} = 0.171, \qquad \frac{(\mu/\rho)\text{ gelatin}}{(\mu/\rho)\text{ aluminum}} = 0.162.$$

μ represents the absorption coefficient and ρ represents density, hence μ/ρ is the mass-absorption coefficient.

The results of the investigation are shown graphically in figure 3. The values of μ/ρ for the six higher potentials manifestly come to a steady value with increasing thickness of absorbing material.

In figure 4 are plotted log V and log μ/ρ in which the values of μ/ρ are the limiting values, for the higher potentials, and the lowest values obtained, for the lower potentials. The points for the six higher potentials lie very close to a straight line, the slope of which indicates

$$\frac{\mu}{\rho} V^{2.77} = \text{constant}.$$

The other points do not represent the limiting values of μ/ρ, and hence would be expected to lie above this line. The mean value of the constant is 4.24×10^{12}; hence

$$\frac{\mu}{\rho} = \frac{4.24 \times 10^{12}}{V^{2.77}}. \tag{1}$$

The six values of μ/ρ as given by this formula agree to within less than one per cent with the observed values.

If the 'end' radiation, which is homogeneous according to the absorption test, has a definite frequency given by the quantum theory relationship

$$Ve = h\nu, \tag{2}$$

then

$$\frac{\mu}{\rho} = 19.4\lambda^{2.77}. \tag{3}$$

The mass per square centimeter of aluminum, ρd, which was found necessary to render the X rays approximately homogeneous, is given, as nearly as could be observed, by

$$\rho d = 10^{-12} \times V^{2.77}. \tag{4}$$

It has been known for some time that an equation of the form of (3) would represent roughly the relationship between absorption coefficients and wave lengths, but the exponent has been estimated by Bragg,[1] who is perhaps the foremost observer, at from 2.5 to 3.0, whereas these results indicate it to be 2.77 ± 0.03. Bragg's estimate is based on the absorption coefficients of monochromatic rays obtained by the use of the X ray spectrometer. It has also been known[2] that X rays produced at steady potentials become homogeneous after passage through a sufficient thickness of absorbing material. However, no formula such as (4) has been given by which to estimate the necessary thickness. Data similar to those on which equation (1) is based have been used by Duane and Hunt[3] and by Rutherford, Barnes and Richardson[4] to calculate wave lengths by means of relationships similar to (3),

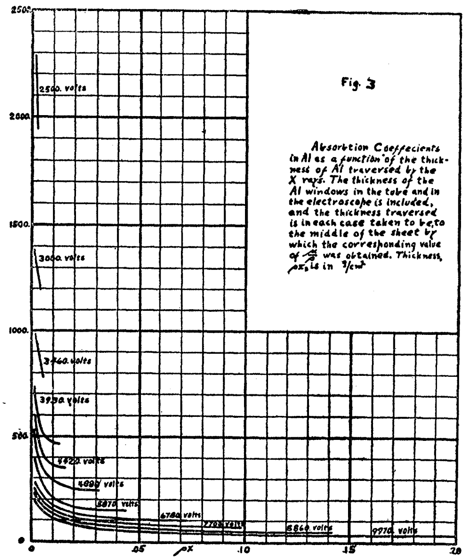

Fig. 3

Absorbtion Coeffecients in Al as a function of the thickness of Al traversed by the X rays. The thickness of the Al windows in the tube and in the electroscope is included, and the thickness traversed is in each case taken to be, to the middle of the sheet by which the corresponding value of $\frac{\mu}{\rho}$ was obtained. Thickness, ρx, is in g/cm²

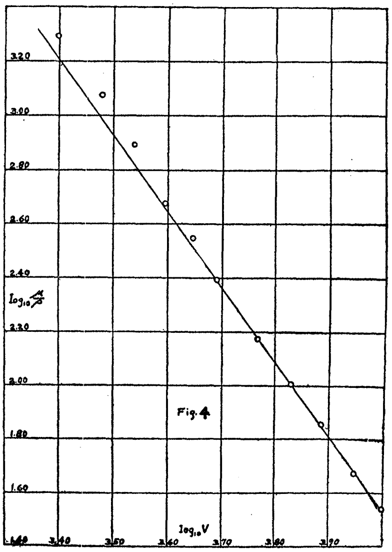

Fig. 4

although the constants in this equation were not accurately known, and thus to test the quantum relationship (2). The results of Hull[5] indicate clearly that the quantum relationship (2) holds for the maximum or limiting frequency of the X rays produced at high potentials, but although the range of potentials used by Rutherford (13,200 to 175,000 volts) was sufficient for the accurate determination of the constants of (1) or (3), they cannot be determined from his results, either because such relationships do not hold for very high potentials, or because the X rays had not passed through a sufficient thickness of absorbing material to give the limiting values of the absorption coefficients. The X rays produced at the potentials used by Rutherford and by Duane are of such penetrating power that no special window such as W, figure 1, was necessary. X rays produced at the potentials used in this investigation (2,500 to 10,000 volts) are of such low penetrating power that it was necessary to make the window W as thin as could be made to withstand atmospheric pressure, and to use the thinnest sheets of absorbing material that could be obtained, and still have them of uniform thickness.

Summary.—A relationship such as (3) has been known for some time to hold approximately for X rays of the ordinary range of penetrating power, but the constants have not previously been accurately determined. These results indicate that such a relationship holds for very much softer X rays, and values of the constants have been determined with considerable accuracy. These values are in agreement with those which hold for the higher potentials, as nearly as the latter have been determined.

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[1] W. H. Bragg and W. L. Bragg, *X Rays and Crystal Structure*, p. 180. W. H. Bragg *Phil. Mag.*, March, 1915.

[2] Wm. R. Ham, *Physic. Rev.*, January, 1910.

[3] Duane and Hunt, Proc. Amer. Phys. Soc., *Physic. Rev.*, August, 1915.

[4] Rutherford, Barnes and Richardson, *Phil. Mag.*, September, 1915.

[5] Albert W. Hull, Proc. Amer. Phys. Soc., *Physic. Rev.*, January, 1916.

FURTHER EVIDENCE AS TO THE RELATION BETWEEN CROWN GALL AND CANCER

By Erwin F. Smith

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Read before the Academy, April 18, 1916. Received, June 15, 1916

1. *Fundamental concepts.*—It is my belief that a diligent study of tumors in plants will help to solve the cancer problem. Expressed in other words, my text is this: Cancer occurs in many kinds of plants in which it passes through an essentially parallel course of development